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MANAGEMENT OF GEOLOGICAL MAP UNITS IN A GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

A major hindrance to the computerization of bedrock geology maps is the difficulty of rationalizing map units between maps. Levels of subdivision, unit labels and legends are usually incompatible on maps prepared at different times, at different scales, or by different authors.

A relational database has been constructed as part of a Geographic Information System (GIS), currently using CARIS™, Ingres™ and Helix Express™ software. The database allows map units to be reclassified consistently between maps. The applicability of the system to a variety of geological situations has been tested by entering data for about 13 percent of the area of insular Newfoundland, and coverage is being increased on an ongoing basis.

The system uses a single set of linework, digitized from bedrock geology maps at the most detailed scales available. For each area, the most current or the most reliable map is chosen, and then maps for different areas are joined together within the GIS to form a continuous collage of polygons. No changes are made to the linework as originally published, so some mismatches remain at map boundaries. Each polygon has a unique identifier, which links it to the database, and allows the retrieval of information pertaining to that polygon.

A map can be generated for any part of the continuous coverage, irrespective of the boundaries of the original geological maps or of NTS areas. The level of detail can be varied to suit a variety of scales and uses without compromising the spatial accuracy of the linework. The database produces a consistent set of unit labels, a legend and a list of references to source maps and legend descriptions; all of these are specific to the selected area and reflect the level of detail chosen for the map. Linework and data files can be dumped for use with other systems; a large part of the existing file has been loaded into ArcView™, where the resulting map can be searched interactively by unit, age, rock type and other bedrock-related criteria. New variables can be added to the database to allow generation of thematic maps that, instead of showing bedrock directly, show some feature that is dependent on bedrock such as mineral potential.

INTRODUCTION

The most obvious feature of a geological map is the division of the mapped area into smaller areas, each underlain by a distinguishable geological unit, a *map unit*. Each unit is labelled on the map and the label can be referred to a legend, which provides information about the rocks that underlie that particular area, such as a lithological description, age and stratigraphic classification.

Most map units cover sufficiently large areas on the ground that their boundaries, when plotted on a map, define two dimensional *polygons*. However, some map units, such as dykes, are too narrow to have their widths shown on the map and are indicated by *lines*. Other map units consist of single exposures and are depicted as *points*. Whether the map unit is represented on the map by a polygon, a line or a point, it always refers to a particular kind of rock or rock assemblage that a geologist found to be distinguishable from other rocks

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in the area. It is distinct from some of the other features shown on a geological map, such as structural measurements, mineral occurrences, isograds or faults.

The classification of rocks into map units is a subjective process. Some important factors that influence it are:

1) the tendency of an individual geologist to "split" or "lump" rock types,
2) the preconceived ideas of a geologist concerning the significance of particular lithological contrasts,
3) the pre-existing stratigraphic classification of the rocks,
4) regional and global geological theories current at the time of mapping, and
5) the scale of mapping.

Because of this subjectivity, systems of map units are seldom compatible on neighbouring map sheets prepared by different geologists, and quite often are incompatible between areas mapped by the same geologist.

The labelling of map units also tends to be peculiar to individual map sheets. If a numerical system is used, units within an area are numbered from 1 upward and any compatibility with neighbouring maps is fortuitous. If an alphanumeric system is used, certain conventions may be followed, but few geologists try to use labels that match those on neighbouring maps.

The incompatibility of map units and unit labels between maps means that a separate map legend must be compiled for each map and is only applicable to that map. This is so in a horizontal sense, between neighbouring maps of comparable scales, and it is also so in a vertical sense between maps of different scales for the same area. Small-scale, compilation maps are generally divided into less detailed units than large-scale maps and impose unit and labelling schemes that mostly differ from any of the schemes used on the more detailed source maps.

Another kind of incompatibility between neighbouring geological maps lies in the positioning of geological contacts. There are two fundamental reasons why contacts may not match exactly between maps. The first is a natural outcome of different systems for defining map units; units that do not represent the same packages of rocks should not match across map boundaries. The second is the way that individual geologists interpret the positions of contacts in places where the contacts have not been directly observed. Mismatches of this kind may be just matters of interpretation, if the quality of exposure is simply not adequate to provide a unique solution, or they may reflect different degrees of control based on different amounts of exposure or different densities of observation.

The subjective nature of map units and the problems that result have hindered the application of computer technology to geological map production. Computers are still largely restricted to a cartographic role, producing maps that, like their pre-computer forebears, have to be drawn (or digitized) individually, have incompatible map units and labelling schemes, and have legends that have to be compiled specifically for each map. In a Geographic Information System (GIS), these maps are little more than templates, forming the backdrop to more versatile layers of, for instance, geochemical and geophysical data. The latter use numeric data, making them easily searched, scaled, joined and manipulated in ways that fully use the data-processing capabilities of computers and allow products to be customized to particular needs.

MAP UNIT CONVENTIONS

Despite the subjectivity of geological map units, there are certain conventions that are generally observed by geologists. Four of these have been used as starting points for organizing units in this database.

1) At detailed scales, map units are usually named and organized on a legend according to a hierarchical system of stratigraphy (North American Commission on Stratigraphic Nomenclature, 1983). Thus, a particular unit may be part of a Member, which is part of a Formation, which is part of a Group, which in turn is part of a Supergroup.
2) At less detailed scales, units tend to be organized along more interpretive lines into tectonic lithofacies, which are assigned to tectonostratigraphic zones and subzones (Williams, 1978; Williams *et al.*, 1988), again in a hierarchical fashion.
3) On many maps, unit labels are alphanumeric and the sequence of letter symbols often indicates, first the age of the unit, and then the stratigraphic entities to which the unit belongs in descending order through the stratigraphic hierarchy. Thus the label 'OBSv' might indicate a volcanic unit (v) belonging to the Sandy Lake Formation (S) of the Buchans Group (B), which is of Ordovician age (O).
4) Map legends are generally ordered on the basis of some combination of age, stratigraphic classification, tectonostratigraphic zone, and rock class.

OBJECTIVES

The map-unit database and its link to CARIS™, a software package used as the graphical component of the GIS, allow the following objectives to be met from a *single* set of digitized maps.

1) Production of maps depicting a range of geological detail, from that shown on the 1:1-million lithofacies

map of insular Newfoundland (Colman-Sadd *et al.*, 1990), through maps showing undivided groups or formations, to maps showing all subdivisions distinguished by the field geologists. This flexibility allows production of maps with geological detail that can be varied both between maps and within maps and is appropriate to any scale or use.

2) The ability for the user to be able to select any area, irrespective of NTS or geological map boundaries, and produce a geological map that has a usable degree of internal consistency.
3) An alphanumeric labelling system that is consistent within a map and from map to map, and which reflects the level of geological detail selected by the user.
4) A list-style legend that: (a) includes all units that are present in the selected area, at the selected level of detail, and no other units, (b) gives a standard description of the units, at the selected level of detail, along with appropriate titles for age, stratigraphic classification, tectonostratigraphic zone, and rock class, and (c) organizes and orders units according to age, tectonostratigraphic zone, rock class, or some combination of the three, at the option of the user.
5) Data listings that can be imported into any database to allow searches for units based on age, stratigraphic classification, tectonostratigraphic zone, rock class, lithologic keywords, text strings within unit descriptions, and other variables.
6) A list of references for map unit contacts and legend descriptions for the selected area, and only the selected area.

As well as meeting the above objectives, which concern output, the database has also been designed to make data input easy, consistent and accurate. Although the system can be used for single maps, where data input presents few problems, it is principally intended as a means of drawing together tens or hundreds of disparate geological maps on a regional scale. With this objective in mind, a special emphasis has been placed on automating data entry, mainly through the use of menus, and on making it easy to make global changes of key variables.

SYSTEM OVERVIEW

DIGITIZING MAPS

The most recent geological map for a given area is digitized (see Colman-Sadd *et al.,* 1995, for an index to these maps for insular Newfoundland). In most cases, this source map will have been published previously. If It has not, it should be published separately so that there is a clearly identifiable, "authorized" version, which is entirely the work of the geologist(s) concerned and can be referenced. A copy of the digitized map is stored as a separate archived file. A second copy is joined to neighbouring maps as part of a mosaic that will eventually cover all of the island of Newfoundland. At each location on the mosaic, the map that is used is the one that is deemed to be the most reliable and informative for that location. The mosaic is therefore constructed from maps by many different authors, originally published at several scales over the course of the last fifty years. A map in the mosaic is not necessarily reproduced in its entirety if parts of it have been superseded by later work. In Figure 1, the original maps by Dean (1977) in NTS 12H/8 and 2E/5 showed the whole of each NTS area and were contiguous. However, the parts of those areas underlain by the Roberts Arm Group have since been remapped by Bostock (1988) and Swinden (1987) and their maps are used in preference to Dean's (*op. cit.*). Away from the Roberts Arm Group, Dean's mapping continues to be the most reliable. In the mosaic, each area mapped by a particular geologist is surrounded by a boundary, which is shown by a special line type on maps produced from the system.

All contacts, faults and other linework on source maps are digitized without any alteration to either their positions or their attributes (e.g., defined, approximate or assumed).

Each polygon, line or point representing the occurrence of a map unit (henceforth referred to collectively as polygons) is assigned a unique identifier. The identifier has two parts, the number of the source map, as used in the Newfoundland Geological Survey's Geofiles, and the number of the polygon within that map. For instance, the map produced by Colman-Sadd and Russell (1988) for the Miguels Lake area is 002D/12/0197 and the polygons within it are numbered from 1 upward. The two parts of the identifier are used separately in the database, but are converted to a single abbreviated string for use in CARIS™ (e.g., DM012_001 for the polygon 1 in the Miguels Lake area).

RECLASSIFICATION OF MAP UNITS

The database contains a list of the unique identifiers for all the polygons in the mosaic of maps. For each polygon, it also contains the unit label that was assigned to the polygon on the original, published map. Thus, on map 002D/12/0197, polygon 35 was originally labelled as Unit 13, which was shown on the legend as the North Steady Pond Formation; obviously Unit 13 means very little outside the context of this particular map and legend.

The first procedure in the database is to reclassify the original map units according to schemes that are compatible

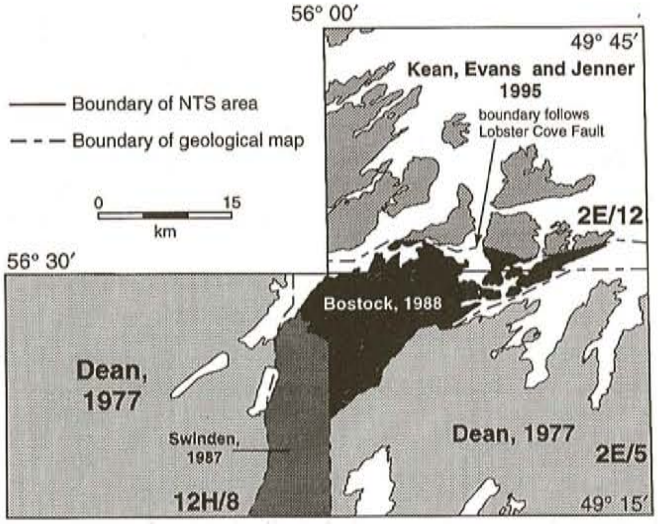


Figure 1. *Index map for NTS map areas 2E/5, 2E/12 and 12H/8, showing the distribution of bedrock-geology source maps used in making the continuous mosaic of maps for this region.*

between map sheets. Two different classification schemes are used so that two different types of map can be produced.

1) For the production of detailed maps, the classification scheme is based on the stratigraphic code. Each unit is classified in terms of its supergroup, group, formation, member, and three levels of subunits for unnamed subdivisions. Non-stratified units are classified using the equivalent lithodemic ranks (North American Commission on Stratigraphic Nomenclature, 1983). Unit 13 on map 002D/12/0197 belongs to the North Steady Pond Formation of the Baie d'Espoir Group; the other five levels in the classification are not specified and are left empty in the database. Ideally, the number of subunit levels should be open-ended, but such increased flexibility would make consistent data entry more difficult and would produce excessively long unit labels. Three subunit levels have been found to be adequate for maps entered so far but, if this is not the case in the future, further levels can be added.
2) For the production of small-scale lithofacies maps, the classification is based on the units shown on the 1:1-million bedrock-geology map of insular Newfoundland (Colman-Sadd *et al.*, 1990). Although the divisions on the 1:1-million map do not use stratigraphic names and are not compatible with the stratigraphic code, it is a simple matter to reclassify a map that is based on the code in terms of 1:1-million units. Unit 13 on map 002D/12/0197 was assigned to unit 'COv' (for Cambro-Ordovician volcanic rocks) on the original, printed map, and in the database is assigned to unit 'COvx', where 'x' indicates the part of unit 'COv' that outcrops in the Exploits tectonostrati-graphic subzone.

RELABELLING OF MAP UNITS

Once map units have been reclassified under schemes that have universal application, they can then be relabelled in ways that are consistent from one map sheet to another. Two methods of relabelling are used to correspond to the two reclassification schemes.

1) Detailed maps use the alphanumeric system commonly found on Geological Survey of Canada maps. The first part of the label indicates the age of the map unit, which is derived from information previously entered into the database specifying the age of the top and base of each unit. The age part of the label, for which a special font would be used on final maps, is followed by letters indicating the various subdivisions of the stratigraphic hierarchy to which the unit belongs. The label for Unit 13 on map 002D/12/0197 is 'OBN', where 'O' stands for Ordovician, 'B' for Baie d'Espoir Group, and 'N' for North Steady Pond Formation. The letter, 'B', is assigned to the Baie d'Espoir Group independently of any map sheet and is generated as a part of the label for any unit that is classified as belonging to the Baie d'Espoir Group, no matter where it occurs. Likewise the letter, 'N', is always used for units classified as part of the North Steady Pond Formation (of the Baie d'Espoir Group). In a neighbouring map area, the North Steady Pond Formation is divided into volcanic and sedimentary sub-units and these would be labelled 'OBNv' and 'OBNs', respectively. A procedure is provided in the database to check whether different units generate the same label. If this happens, it is easy to change the letters assigned to units.
2) Small-scale lithofacies maps use the labelling scheme on the 1:1-million map of insular Newfoundland, slightly modified to distinguish subzones and update certain units. The label is the same as the identifier that is used when units are reclassified, e.g., 'COvx'.

BASIC PROCEDURE FOR GENERATING A MAP AND LEGEND

1) The user selects an area in CARIS™ for which a geological map is required. The area does not need to conform to NTS map boundaries or boundaries between published geological maps.
2) CARIS™ extracts a copy of the part of the map mosaic that lies within the selected area and uses this template to produce the map.

3) CARIS™ lists all the polygons within the selected area, identifying each one uniquely by a combined map and polygon number (e.g., DM012_035, which is converted to separate map and polygon numbers in the database).
4) The polygon list is loaded into the database.
5) The user instructs the database to produce either a lithofacies map or a map based on the stratigraphic hierarchy; if the latter is selected the user also specifies the level(s) of detail (see below).
6) The database determines standard unit labels for all the polygons and produces a list of these labels attached to their respective polygon identifiers.
7) The polygon and label list is loaded into CARIS™ and unit labels are placed in the appropriate polygons. The map can now be coloured using the unit labels as a guide.
8) The database constructs a legend for the units represented on the polygon list, at the correct level(s) of detail, using previously entered descriptions and other necessary information. The legend is dumped to a text file.
9) The database lists references to publications used as sources of linework or legend descriptions. The list is dumped to a text file.
10) The text files for the legend and references are formatted and imported into CARIS™ or other cartographic software for insertion alongside the map.

LEVEL OF DETAIL

The system can produce maps and corresponding legends at any level of detail and the level of detail can be different for different units on the same map. For instance, the geological map for the northern part of the Buchans – Robert's Arm belt in Open File NFLD/2513 (Liverman *et al.*, 1995) shows the Roberts Arm Group subdivided at the same level of detail as is seen on the originally published maps. All surrounding units, including the Wild Bight and Cutwell groups, were of peripheral interest from the point of view of this publication and are shown undivided. It is also possible to show a unit as undivided except for certain specified subunits. For instance, if felsic breccias were considered to be prime exploration targets in the Roberts Arm Group, the system could be instructed to produce a map in which the Roberts Arm Group is shown undivided except for units of felsic breccia.

The user of the system has an initial choice between a lithofacies map or a map based on the stratigraphic hierarchy. If the lithofacies map is chosen, each polygon is given the appropriate label from the 1:1-million map of insular Newfoundland. This map is very generalized. In the Roberts Arm Group, for example, eleven units shown by Bostock (1988) and represented by polygons on the digitized map are reduced to two units, 'COvn' and 'COsn', standing for Cambro-Ordovician volcanic and sedimentary rocks of the Notre Dame Subzone, respectively. Once the labels have been assigned to individual polygons, CARIS™ compares neighbouring polygons and, if they have the same labels, as many of them will, it dissolves the contacts between them (if the contact is a fault, the fault is retained). The map is thus reconstructed into larger polygons that reflect the chosen level of detail.

If the user chooses to produce a map based on the stratigraphic hierarchy, a similar procedure is followed but there is more flexibility. Map 002D/12/0197 shows two formations of the Baie d'Espoir Group, the Salmon River Dam Formation and the North Steady Pond Formation; they are designated on the published map as Units 11 and 13, respectively. In the database, these units are reclassified using their group and formation names. The database then generates unit labels 'OBS' and 'OBN' respectively, where 'B' stands for Baie d'Espoir Group and 'S' and 'N' for the formation names. If the system is instructed to produce a map showing the Baie d'Espoir Group divided into formations, it produces these labels and inserts them into the appropriate polygons. When CARIS™ checks the polygon labels, it finds that they are different and leaves the contacts in place. If, on the other hand, the system is instructed to show the Baie d'Espoir Group as an undivided group, the database truncates its classification of the units at the group level. It then produces 'OB' as the label for both Units 11 and 13. When this label is applied to polygons in CARIS™, contacts between neighbouring polygons of the Salmon River Dam and North Steady Pond formations are dissolved because both polygons are now simply labelled 'OB', indicating Baie d'Espoir Group. In the first case, the legend shows entries for 'OBS' and 'OBN' with descriptions of each formation; in the second case, it has a single entry for 'OB' and a description of the Baie d'Espoir Group as a whole.

COMPOSITE VERSUS COMPILATION MAPS

It is proposed to refer to maps generated by the system as "composite" because the mosaic from which they are produced is a composite layer of digitized geological maps. Composite maps are distinct from traditional compilation maps in a number of ways.

1) Composite maps potentially show the same level of detail as the source maps from which they were derived; as described above, it is at the option of the user whether this detail is actually printed out in any given circumstance. Compilation maps show less detail than at least some of their source maps.
2) Composite maps are designed to be produced at the

same scale as their source maps, if the user so chooses. Compilation maps are usually produced at smaller scales than at least some of their source maps.

3) On composite maps, the positions and attributes of contacts are not changed from those on the source maps. On compilation maps, line work is altered so that there are no mismatches across the boundaries between source maps.
4) On composite maps, unit information and stratigraphic classification are updated and descriptions are standardized for clearly equivalent units. However, because contacts are not changed, the actual packages of rocks included in particular units are not changed. On compilation maps, the packages of rocks that constitute particular units may be altered in order to remove mismatches across source-map boundaries.

By its nature, a composite map has numerous mismatches of units at source-map boundaries. The mismatches represent gaps and uncertainties in information about the geology. An attempt to remove them replaces the opinions of geologists in the field with the opinion of a compiler, who may never have been to the area in question. On a compiled map, the alteration of information is an acceptable trade-off for the greater readability of the map because its effect is minimized by the reduction in scale and detail on the final product. On a composite map, this is not so because the map will commonly be used at the same scale and detail as the source maps. Mismatches should be viewed as a source of information in themselves. They convey a sense of the uncertainty of the geological information in an analogous way to error estimates provided with radiometric dates. Although mismatches do interfere with the readability of the map, the most serious problems in this regard are overcome by the relabelling of units using one of the two standard schemes.

A composite map is not the same as a compilation map, but it does do much of the work involved in compilation. In most cases, a suitably generalized composite map of an area requires only the harmonization of contacts at map boundaries to make it into a traditional compilation map.

CREDITS ON COMPOSITE MAPS

There are four kinds of input into the geological content of a composite map. It is proposed to credit them accordingly:

1) Line work and original unit designations are taken from the source maps. On a composite map, a special line type outlines the boundaries of the source maps. In addition, an index map shows the distribution of these maps and keys them to a reference list.
2) Descriptions in the legend are individually referenced. If a unit occurs on several maps by different authors, each author will have written a description. Only the one that is deemed to be most informative is entered into the database as the standard description for the unit. Thus a map and the unit descriptions that are attached to it may have come from different sources and therefore need to be referenced separately. Furthermore, generalized units may never have been used undivided on a map and so legend descriptions for them may not exist. For instance, a map derived from Dean (1977) showing the undivided Wild Bight Group cannot use a description from his map because all the descriptions refer to subdivisions of formations within the group. Instead the database uses a description from the Lexicon of Canadian Stratigraphy (Williams *et al.*, 1985).
3) The compiler of the database must classify map units using the two schemes described previously. Information is also entered about the age and lithology of units, and a legend description has to be chosen or written. Although lithological descriptions mostly conform to those on the source maps, age information is often substantially different, reflecting major advances in dating rocks in recent years. The compiler of the database is named at the margin of the map.
4) A judgement must be made about which is the most reliable map for a given area. In many cases, this is a straight forward process of choosing the most recent map. However, geologists making thematic maps with no set areal limits often do reconnaissance mapping adjacent to their main areas of interest and include this work on their final maps; other geologists compile material from existing maps to complete an NTS area. An example occurs in NTS 2E/12 where the maps of Bostock (1988) and Kean *et al.* (1995) overlap (Figure 1). Bostock mapped the fringes of the Lushs Bight Group, north of the Lobster Cove Fault, but his main effort was concentrated south of the fault in the Roberts Arm Group. Kean *et al.* (1995) show the geology for the entire NTS area on their map, but their field work was mainly in the rocks north of the Lobster Cove Fault and the part of the map south of the fault was compiled from an early version of Bostock's map. On the mosaic of maps, parts of both maps are discarded and the join is placed along the Lobster Cove Fault. The person responsible for making these decisions is named at the margin of the map.

Authorship of a composite map does not reside totally with any of the people who have geological input. The proposed recommended citation names the Geological Survey rather than any specific author.

HARDWARE AND SOFTWARE

At present, the system uses a variety of hardware and software to produce a map.

Digitizing is done using RootsPro™ software and a tablet attached to an 80386 or 80486 microcomputer running MS-DOS™. Digitized linework is imported into CARIS™, which is the graphical part of the GIS and runs on an HP 9000/755 server. Maps are joined together in CARIS™ and preliminary versions are prepared. Polygon lists are exported from RootsPro™ and CARIS™ as text files and editing of the lists is done in a spreadsheet program. The text files are imported into the database, which is a Helix Express™ application running on a Power Macintosh 7100/80. Helix Express™ produces text files of:

1) Unit labels, which are imported into CARIS™ for labelling the map polygons. Ingres™ is used on the server for database functions that need to be directly interfaced with CARIS™.
2) Legends, which are formatted in a word processor and imported into: a) CARIS™ or IslandDraw™ for final cartographic work on the server, prior to plotting paper versions of the map, and b) ArcView™ for interactive use on a microcomputer and output of paper copies.
3) Data listings, which are imported into ArcView™ to allow the interactive selection of units, using such criteria as age and rock type, as well as the interactive ability to show the geology at various levels of detail. In ArcView™, layers of other data types such as structural measurements, geophysics or geochemistry can be superimposed on the geology maps.
4) Reference lists, which are formatted in a word processor and imported into CARIS™, IslandDraw™ or ArcView™.

Eventually it is intended to integrate most functions on a server, where the graphical tasks would be performed by CARIS™ and the database tasks by ORACLE™. However, it should be possible to rewrite the system for any GIS.

STRUCTURE OF THE DATABASE

The generation of unit labels, legends, data listings and reference lists is controlled by a relational database consisting of eleven interrelated tables. Six of the tables are used for the input and storage of data; five tables are used for the manipulation and output of data. Only one of the five output tables (Figure 9) is actually visible to the user; the other four (*Tables 8, 8a, 9* and *10*) operate in the background, where they are used to import and export text files of the data. (All references to numbered tables in this report pertain to tables in the GIS, and are written in italic script; where examples of the GIS tables are presented, they are designated as figures.)

INPUT TABLES

Table 1: Polygon IDs

Figure 2 shows the form presented to the user for the input of information about individual map polygons. The form lists the variables in the first column and has spaces to enter values in the second column; a new form appears on the screen for each record. The form also has buttons that can be clicked with the mouse to perform various functions. Although data can be typed directly into the fields, the normal method of entry is to load a text file that has been compiled in a spreadsheet program by the person digitizing the map. Figure 3 shows a data listing of a number of records, each occupying one row, with the variables shown as columns; a list such as this would be produced by clicking the 'Print polygon list' button (Figure 2).

Variables

Map ID is the number assigned to an individual geological source map. It is the same as the index number for that map in the Geological Survey's Geofiles, if one is available; otherwise one must be created. The field must be filled.

Map reference is a computed variable, derived from *Table 6* (see Figure 8), showing the short-form reference for the map in 'Map ID'. On all forms, computed fields have italicized, non-bold labels; they cannot be typed into.

Polygon ID is the number assigned to a polygon within a geological map. For each map, areal polygons are numbered sequentially from 1 to 1999; lines representing occurrences of units are numbered from 2000 to 2999, and points from 3000 upward. The field must be filled and each polygon is identified uniquely by a combination of 'Map ID' and 'Polygon ID'.

Unit ID is the unit label that was applied to a polygon on the original source map. The field must be filled.

Priority. If a polygon has a simple unit label, e.g., 'Ssa', one record is created for that polygon and the value of 'Priority' is 1 (Figure 3, Polygon 16). If it has a compound label indicating two unseparated units, e.g. 'Ssa, Ssb', two records are created with the same polygon number (Figure 3, Polygon

Map ID	012A/0432
Map reference	Thurlow and Swanson, 1981
Polygon ID	187
Unit ID	5Ae
Priority	1
Added charact.	?

Open input table:

- [*] Table 2: Unit IDs
- [*] Table 3: 1 to 1 million
- [*] Table 4: Unit descriptions
- [*] Table 5: Timescale
- [*] Table 6: References

Go to "Output Selection": [* * * * *]

Load text file: [* * * * *]

Select records: [* * * * *]

Post Map and Unit IDs to Table 2: [* * * * *]

Print polygon list: [* * * * *]

Delete multiple records: [* * * * *]

Figure 2. Table 1: *Polygon IDs. Form used for entering polygon data. Labels in Roman type indicate variables entered directly into the table; bold Roman type is used for variables that are posted to other tables. Labels in italics indicate variables derived from another table; plain italics are used for calculated variables and bold italics for variables that have been posted. Variables for all tables are described in the text.*

Map ID	*Poly ID*	*Unit ID*	*Priority*	*Added Char.*
NFLD/0979h	16	Ssa	1	
NFLD/0979h	17	Ssa	1	
NFLD/0979h	17	Ssb	2	
NFLD/0979h	18	Ssb	1	
NFLD/0979h	19	Dg	1	
NFLD/0979h	20	OB	1	?
NFLD/0979h	21	Sm	1	
NFLD/0979h	22	C	1	?
NFLD/0979h	23	Dp	1	

Figure 3. *List showing a selection of records from* Table 1. *Note the presence of two records for polygon 17 with different priority values; these allow compound labels to be built for polygons (e.g., 'Ssa, Ssb'). The question marks in the 'Added characters' field indicate polygons where the geologist was uncertain about the assigned unit and added a question mark to the original label.*

17). In the first record, 'Unit ID' is 'Ssa' and 'Priority' is 1, and in the second, 'Unit ID' is 'Ssb' and 'Priority' is 2. A third label would have a 'Priority' of 3, and so on. The unit that has a 'Priority' of 1 is the dominant unit and is used to control the colour of the polygon on the final map, but all units in the polygon are represented in the label and all units appear on the legend. The 'Priority' field must be filled and a record in *Table 1* (Figures 2 and 3) is uniquely identified by a combination of 'Map ID', 'Polygon ID' and 'Priority'.

Added characters. A geologist may have been uncertain about assigning a polygon to a particular unit and added a question mark to the label, e.g., 'OB?' The question mark should be placed in this field. It will then be added to the label on the map, but it will not generate a separate unit, 'OB?', on the legend. A distinction must be made between polygons of uncertain assignment and units of uncertain assignment. If the polygon is of uncertain assignment, the original map legend will have one entry for the unit ('OB' in the example above) and the question mark is placed in the 'Added characters' field. If the unit is of uncertain assignment, there will be two entries in the legend, one for unit 'OB' and one for unit 'OB?'. In this case, the question mark should be treated as part of the unit designation and included in the 'Unit ID' field; the 'Added character' field should be left blank.

Command Buttons

Open input table. Clicking on one of these buttons opens the entry form for that table.

Go to "Output Selection" opens a form from *Table 7* (see Figure 9), that presents the user with all the command buttons and menus required to generate a map, legend, and data and reference lists for a given area.

Load text file opens a dialogue box so that the user can select a text file to load into *Table 1*; when the selection has been made, the button loads the file. The text file must contain a field for each of the five non-computed variables on the form; each field, except 'Added characters', must be filled on every record.

Select records opens a dialogue box so that the user can select records with particular values of *Table 1* variables.

Post Map and Unit IDs to Table 2 creates a new record in *Table 2* (Figure 4), for every combination of 'Map ID' and 'Unit ID' in *Table 1* that does not already have a *Table 2* record. It then enters the values of 'Map ID' and 'Unit ID' into the appropriate fields in *Table 2*. These two variables are the keys that link *Tables 1* and *2* (Figures 2 and 4). Only those records meeting the criteria defined in the 'Select records' dialogue box are considered for posting.

On all forms, the labels for posted variables are shown in bold; Roman type is used on the source form and italics on the receiving form. Since these variables are always links between tables, changes on one form must be matched by corresponding changes on the other.

Print polygon list prints a list of records in *Table 1* that meets the criteria defined in the 'Select records' dialogue box. Figure 3 shows a typical listing.

Delete multiple records opens a window showing a list of records that meet the criteria defined in the 'Select records' dialogue box. These records can then be deleted by choosing 'Delete All' from the 'View' menu. The button is useful for deleting all the records for a particular map area, so that they can be replaced by a new, corrected, set of records.

The 'Open...', 'Go to...', 'Select...', 'Print...' and 'Delete...' buttons are present on most of the input and output forms, and allow easy access to and manipulation of the information in the database.

Table 2: Unit IDs

Figure 4 shows the form presented to the user for the reclassification of the units on each map sheet, using the 1:1-million map scheme and the hierarchical scheme based on the stratigraphic code (variables 'Supergroup' to 'Sub3-unit').

Variables

Map ID is the number assigned to an individual geological source map. It corresponds to 'Map ID' in *Table 1* (Figure 2) and is entered automatically when the 'Post...' button is clicked in *Table 1*.

Map reference is the short-form reference for 'Map ID'.

Unit ID is the unit label that was applied to a polygon on the original source map. It corresponds to 'Unit ID' in *Table 1* and is entered automatically when the 'Post...' button is clicked in *Table 1*. A record in *Table 2* (Figure 4) is uniquely identified by a combination of 'Map ID' and 'Unit ID'.

1:1-million label is the label to be used for the current unit if the map is redrawn using only the map units shown on the 1: 1-million map of insular Newfoundland. The label cannot be typed in; it must be selected off the pop-up menu, which contains all possible values. The field must be filled and is the key that links *Tables 2* and *3* (Figures 4 and 5).

Supergroup is the name of the supergroup (or lithodemic equivalent) to which the unit belongs, if any. The field may be left blank. Values can be typed in, but when a value is present on one record, it appears on the pop-up menu and should thereafter be selected from the menu. Not only does this save time by eliminating the need to type a name more than once, but more importantly it ensures that the spelling of each name is exactly the same throughout the database.

Group is the name of the group (or lithodemic equivalent) to which the unit belongs, if any. Values can be typed in, taken off the menu, or the field can be left blank.

Formation is the name of the formation (or lithodemic equivalent) to which the unit belongs, if any. Values can be typed in, taken off the menu, or the field can be left blank.

At least one of 'Supergroup', 'Group' or 'Formation' must be defined, even though the map unit may be unnamed. If the unit is unnamed, the user must invent a name and has two choices as to how this name is treated by the database.

1) If the name is to appear on the legend and is to generate a letter as part of the unit label, it is simply treated like a stratigraphic name, and inserted into whichever of the three fields is most appropriate. An example might be "Unnamed ophiolitic rocks", which could be placed in the 'Supergroup' field for any small occurrence of ophiolite that does not belong to a named complex.
2) If the name is to be used only for identification purposes within the database and is not to affect the unit label or appear on the legend, the name is enclosed in round brackets and entered into the 'Formation' field. It is useful to start such "dummy" names with the 'Map ID' where the unit was first encountered; this makes it much easier to distinguish one "dummy" name from another. An example of a "dummy" name is '(012A/09/0685 sediments at Haven Steady)'.

Member is the name of the member (or lithodemic equivalent) to which the unit belongs, if any. Values can be typed in, taken off the menu, or the field can be left blank.

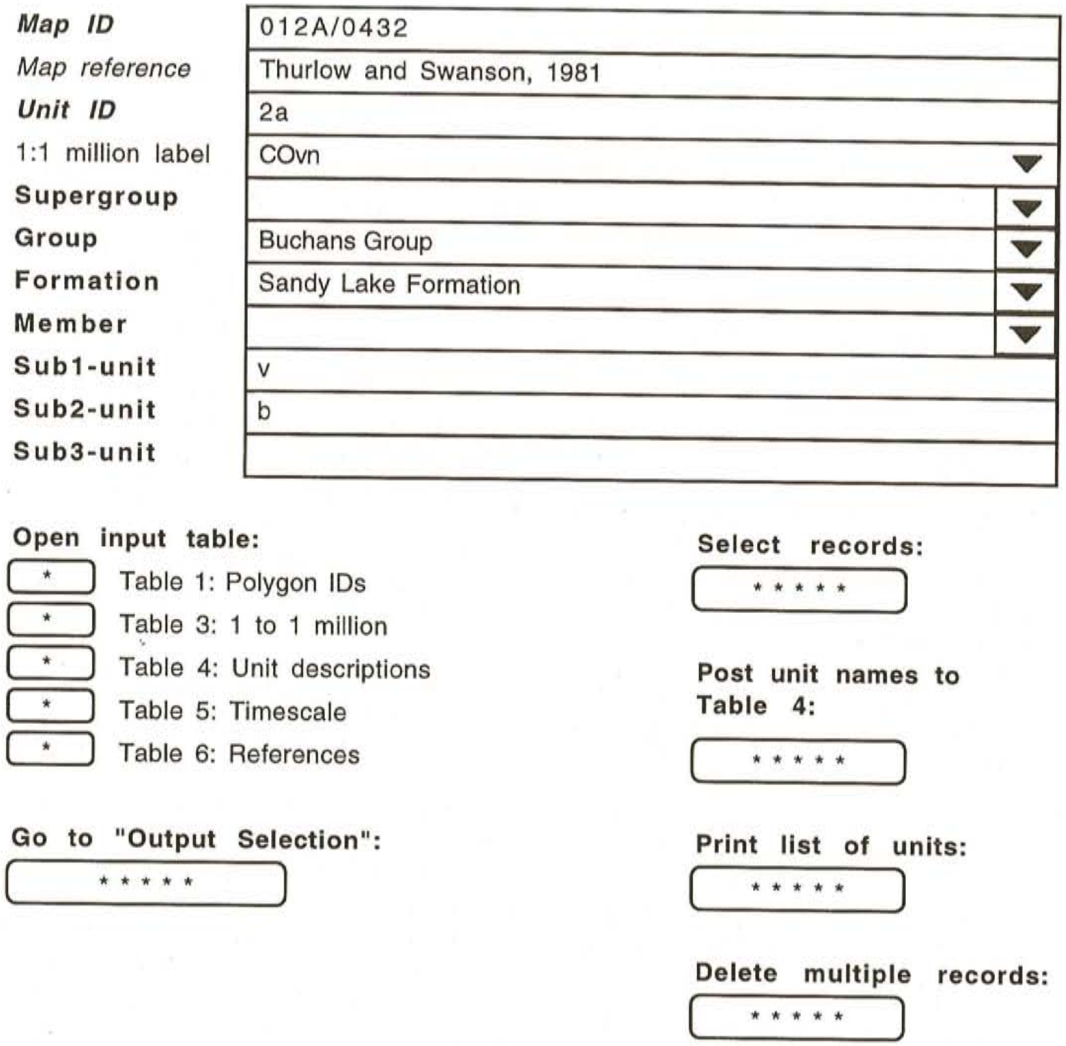


Figure 4. Table 2: *Unit IDs. Form used to classify units, according to the 1:1-million map legend scheme and the stratigraphic code. Clicking on the downward facing triangles produces pop-up menus from which values can be selected. If the triangle is enclosed, values can be typed in as well as being taken off the menu.*

Sub1-unit is a character to identify the first unnamed level of subdivision of a unit. A single letter is preferred and is incorporated into the unit label; more letters can be used if necessary, but care should be taken that they do not make the unit label unmanageably long. The field may be left blank, unless the unit has a "dummy" name and no entry in the 'Member' field, or there is an entry in the Sub2-unit or Sub3-unit fields. The user should try to make subunits hierarchical. For instance, if the unit is one of several volcanic subdivisions in a formation, the user might place all of these subdivisions in Sub1-unit 'v', for volcanic. Then Sub2-unit can be used to distinguish different compositions of volcanic rock, e.g., 'b' for basalt, 'f' for felsic. If the felsic rocks consist of breccia units and tuff units, these might be distinguished by 'x' and 't' in the Sub3-unit field. This would make it possible to produce maps that have all the volcanic rocks lumped together, or the basaltic rocks separated from undivided felsic rocks, or all the units separated as on the source map.

Sub2-unit is a character to identify the second unnamed level of subdivision of a unit. A single letter is preferred and is incorporated into the unit label. The field may be left blank, unless there is an entry in the Sub3-unit field.

Sub3-unit is a character to identify the third unnamed level of subdivision of a unit. A single letter is preferred and is incorporated into the unit label. The field may be left blank.

Command Buttons

Post unit names to Table 4 creates new records in *Table 4* (Figure 6) for each of the stratigraphic units in *Table 2*

(Figure 4) that do not already have *Table 4* records, and enters the names or letters into the appropriate fields in *Table 4*. Only those records meeting the criteria defined in the 'Select records' dialogue box are considered for posting.

Posting of unit names is done for each level in the stratigraphic hierarchy, so that a single record in *Table 2,* with four stratigraphic levels represented, produces four records in *Table 4*. For example, this record in *Table 2*:

Supergroup	Group	Formation	Member	Sub1-unit	Sub2-unit	Sub3-unit
	Buchans Group	Sandy Lake Formation		v	b	

produces the following four records in *Table 4*:

Supergroup	Group	Formation	Member	Sub1-unit	Sub2-unit	Sub3-unit
	Buchans Group					
	Buchans Group	Sandy Lake Formation				
	Buchans Group	Sandy Lake Formation		v		
	Buchans Group	Sandy Lake Formation		v	b	

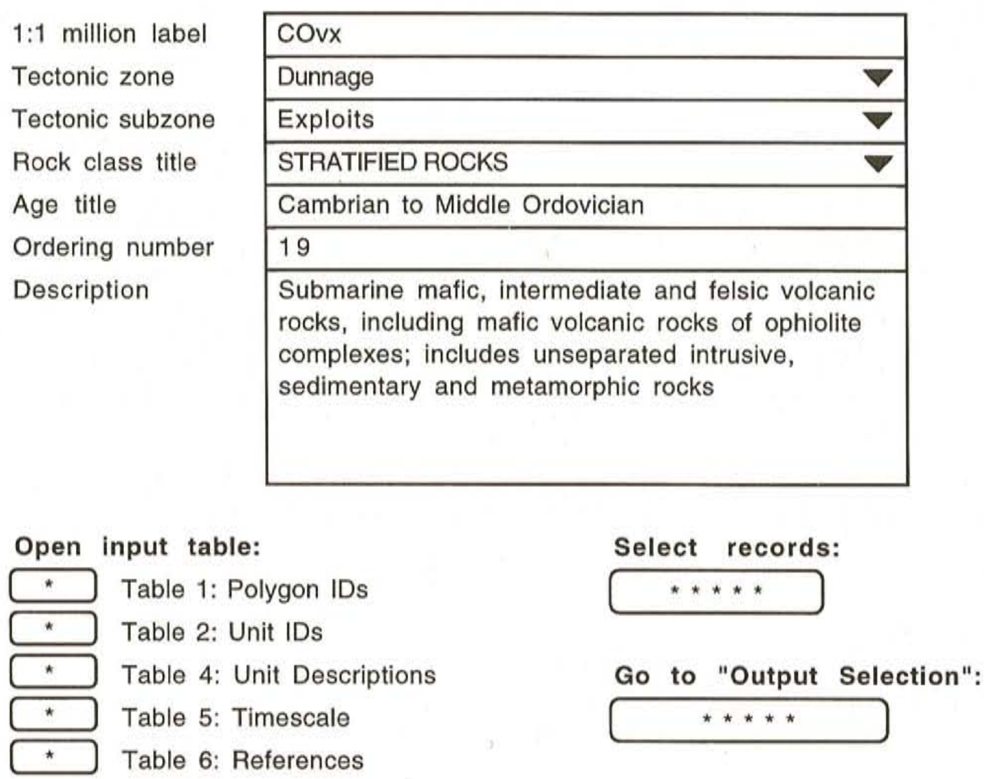


Figure 5. Table 3: *The 1:1-million map. Form used to enter legend information from the 1:1-million map of insular Newfoundland (Colman-Sadd* et al., *1990).*

Computed variables that are derived from the seven stratigraphic variables, from 'Supergroup' to 'Sub3-unit', are the keys that link *Tables 2* and *4* (Figures 4 and 6). In *Table 2*, the computed variable first follows instructions from the user as to what level of detail is desired for the unit, and then lists the requested fields in a continuous string. Thus, if the formation level of detail is requested, entries below this level are disregarded and the computed variable in *Table 2* for the above example is:

Buchans GroupSandy Lake Formation

The computed variable to which this is matched in *Table 4* is a continuous string of the entries in all seven stratigraphic fields. In this example, the computed variable in *Table 2* will find a match in the second of the four records in *Table 4*, and the database will use labels, captions, and age information from this record.

Table 3: The 1:1-Million Map

Figure 5 shows the form presented to the user for entering the information needed to plot a map and legend using 1:1-million map units. *Table 3* (Figure 5) also provides information on tectonostratigraphic zones and subzones, when these are requested as sorting criteria on legends using the stratigraphic hierarchy. For insular Newfoundland, all necessary information is already entered into this table and is unlikely to need frequent revision. Similar information could be entered for other regions.

Variables

The 1:1-million label is the unit label as used on the 1:1-million map of insular Newfoundland. This field is the key that links *Table 3* to *Table 2* (Figures 5 and 4) and the various output tables.

Tectonic zone and *subzone* are fields used to sort legends and generate titles within legends. The values are taken off pop-up menus and cannot be typed in.

Rock class title is used to generate titles within legends. The value is taken off a pop-up menu and cannot be typed in.

Age title is used to generate titles within legends.

Ordering number is used to sort 1:1-million style legends, so that units appear in the same order as on the printed map of insular Newfoundland.

Description is the caption for the unit on a 1:1-million style legend.

Table 4: Unit Descriptions

Figure 6 shows the form presented to the user for entering the information about each unit under the hierarchical scheme based on the stratigraphic code.

Variables

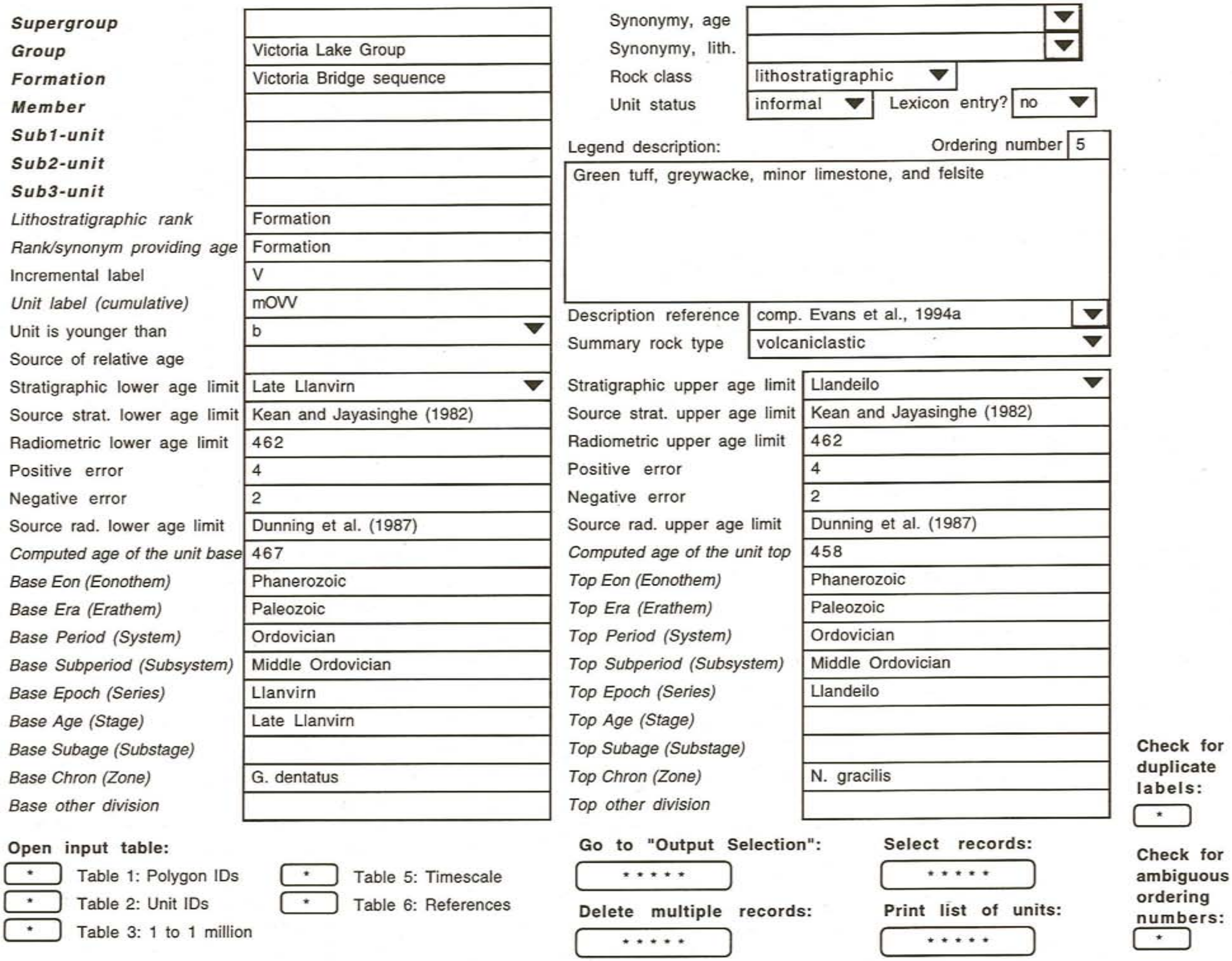
Supergroup, Group, Formation, Member, Sub1-unit, Sub2-unit, Sub3-unit are names and letter-designations for units, as posted from *Table 2*. Collectively, these variables are the key linking *Tables 2* and *4* (Figures 4 and 6). These variables are referred to below as the 'stratigraphic fields'.

Lithostratigraphic rank is the rank of the unit described on the record. It is the same as the label for the lowest stratigraphic field that has an entry.

Rank/synonym providing age indicates the source of age information being used for the record. If age information is entered directly into the record (see below), this variable returns the same value as 'Lithostratigraphic rank'.

Incremental label is the letter (or letters) to be used on the unit label to represent the name entered in the lowest filled stratigraphic field. In Figure 6, the incremental label, 'V', stands for 'Victoria Bridge Sequence'. The following example shows incremental labels for four related records:

Supergroup	Group	Formation	Member	Sub1 unit	Sub2 unit	Sub3 unit	Incremental label
	Buchans Group						B
	Buchans Group	Sandy Lake Formation					S
	Buchans Group	Sandy Lake Formation		v			v
	Buchans Group	Sandy Lake Formation		v	b		b



Supergroup	
Group	Victoria Lake Group
Formation	Victoria Bridge sequence
Member	
Sub1-unit	
Sub2-unit	
Sub3-unit	
Lithostratigraphic rank	Formation
Rank/synonym providing age	Formation
Incremental label	V
Unit label (cumulative)	mOVV
Unit is younger than	b
Source of relative age	
Stratigraphic lower age limit	Late Llanvirn
Source strat. lower age limit	Kean and Jayasinghe (1982)
Radiometric lower age limit	462
Positive error	4
Negative error	2
Source rad. lower age limit	Dunning et al. (1987)
Computed age of the unit base	467
Base Eon (Eonothem)	Phanerozoic
Base Era (Erathem)	Paleozoic
Base Period (System)	Ordovician
Base Subperiod (Subsystem)	Middle Ordovician
Base Epoch (Series)	Llanvirn
Base Age (Stage)	Late Llanvirn
Base Subage (Substage)	
Base Chron (Zone)	G. dentatus
Base other division	

Synonymy, age	
Synonymy, lith.	
Rock class	lithostratigraphic
Unit status	informal
Lexicon entry?	no
Ordering number	5

Legend description:
Green tuff, greywacke, minor limestone, and felsite

Description reference	comp. Evans et al., 1994a
Summary rock type	volcaniclastic
Stratigraphic upper age limit	Llandeilo
Source strat. upper age limit	Kean and Jayasinghe (1982)
Radiometric upper age limit	462
Positive error	4
Negative error	2
Source rad. upper age limit	Dunning et al. (1987)
Computed age of the unit top	458
Top Eon (Eonothem)	Phanerozoic
Top Era (Erathem)	Paleozoic
Top Period (System)	Ordovician
Top Subperiod (Subsystem)	Middle Ordovician
Top Epoch (Series)	Llandeilo
Top Age (Stage)	
Top Subage (Substage)	
Top Chron (Zone)	N. gracilis
Top other division	

Open input table:
* Table 1: Polygon IDs
* Table 2: Unit IDs
* Table 3: 1 to 1 million
* Table 5: Timescale
* Table 6: References

Go to "Output Selection": * * * * *

Delete multiple records: * * * * *

Select records: * * * * *

Print list of units: * * * * *

Check for duplicate labels: *

Check for ambiguous ordering numbers: *

Figure 6. Table 4: *Unit Descriptions. Form used to enter data describing individual units.*

'B' represents 'Buchans Group', 'S' represents 'Sandy Lake Formation', and 'v' and 'b' represent sub-units 1 and 2, respectively. The incremental labels for subunits are the same as the letters entered for them on *Table 2* and posted to the stratigraphic fields in *Table 4*. Subunit labels are entered automatically, but the user must choose letters to represent all named units other than the "dummy" units enclosed in round brackets (see 'Formation', *Table 2*).

Unit label (cumulative) is the map label for a unit, which is computed by stringing together letters representing the age of the unit with incremental labels for each name in the unit's stratigraphic hierarchy:

Supergroup	Group	Formation	Member	Sub1 unit	Sub2 unit	Sub3 unit	Unit label (cumulative)
	Buchans Group						OB
	Buchans Group	Sandy Lake Formation					OBS
	Buchans Group	Sandy Lake Formation		v			OBSv
	Buchans Group	Sandy Lake Formation		v	b		OBSvb

Letters representing the age of a unit ('O' for 'Ordovician' in the above example) are determined using age information entered for the unit in *Table 4* (Figure 6) and referred to the timescale in *Table 5* (Figure 7; see below). In Figure 6, the unit lies entirely within the Middle Ordovician so the age is represented by 'mO'. If new age information becomes available for the unit, this can be entered in *Table 4* and the unit labels will be automatically adjusted. If the geological timescale is changed, the changes can be entered in *Table 5* and all labels for affected units will be adjusted as necessary. Letters indicating age refer to eons in the Archean, eras in the Proterozoic, periods or subperiods in the Paleozoic and Mesozoic, and epochs in the Cenozoic.

There is always the possibility that two different units on the same map may have the same label because the part of a label representing age is a floating value and the number of combinations for a label is fairly limited. If this happens, the problem is easily corrected by changing one of the incremental labels for a unit. Opening the record for the Buchans Group, in the above example, and changing the incremental label from 'B' to 'U' will also change the labels of all the subdivisions of the Buchans Group. For operations within the database, units are not identified by their labels, which may not be unique, but instead by the computed variable that strings together the full names appearing in the seven stratigraphic fields.

Age variables. The age of a unit is used to build a unit label, and to sort units and provide age titles in the legend. Geologists describe the age of a unit in three ways: (a) absolute age, usually derived by radiometric dating and stated in millions or billions of years, (b) stratigraphic age, such as Ordovician or *Didymograptus clingani* Zone, and (c) relative age, based on the Law of Superposition, intrusive relationships or similar criteria. Absolute and stratigraphic ages are interchangeable through the medium of the geological timescale stored in *Table 5*, but they do not have enough resolution to sort most legends. Relative age is important for sorting legends but does not provide information for unit labels or age titles.

Absolute and stratigraphic age data are entered into twelve fields and produce a further twenty computed fields on *Table 4*.

1) *Radiometric lower age limit.* A radiometric age that is considered to define the base of a unit can be entered in this field, together with the positive and negative errors in the two succeeding fields. A field is provided to enter the reference for a radiometric age as an aid to the database compiler.
2) *Stratigraphic lower age limit.* A stratigraphic interval can be entered by selecting a name on the pop-up menu. The menu shows every stratigraphic interval that has been defined in the *Table 5* timescale. Entries cannot be typed into the field and intervals that are not on the menu must be entered by way of *Table 5*. A field is provided to reference a stratigraphic age.
3) *Computed age of the unit base.* The database uses an age in millions of years calculated from the radiometric and stratigraphic lower age limits. For a radiometric age, it uses the age plus the positive error, and for a stratigraphic age, it looks up the age of the base of the interval in the timescale. If there are entries for both radiometric and stratigraphic lower age limits, the computed age is the oldest of these; in the example in Figure 6, the stratigraphic age has overridden the radiometric age. It is useful to enter both radiometric and stratigraphic lower age limits, if these are available, because the one that is

actually used may change, if changes are made to the timescale. The stratigraphic intervals, within which the computed age falls, are listed in the nine fields below the computed age; the fields correspond to the possible values of the 'Rank' variable in *Table 5* (see below).

4) *Upper age limits.* Sixteen fields describing the upper age limits of a unit correspond to the sixteen describing the lower age limits. The 'Computed age of the unit top' uses the youngest of (a) a radiometric age minus its negative error and (b) the age of the top of a stratigraphic interval from the timescale.
5) *Age ranges.* The same entries may be made for both the lower and upper age limits. If a radiometric age of 513 ± 2 Ma is used, the age of the base is 515 Ma and the age of the top is 511 Ma. If 'Ordovician' is entered for both the base and the top, the computed age for the base is the base of the Ordovician (495 Ma), and for the top, the top of the Ordovician (443 Ma).
6) *Missing information.* If a lower age limit is entered as, for example, 'Ordovician', but there is no entry for an upper limit, the database interprets this as meaning the unit is 'Ordovician or younger' and the label for the unit starts with '<O'. If the upper limit is filled but not the lower, the unit is 'Ordovician or older' and the label starts '>O'.

Most units do not have direct age information of their own, they are simply known to fall somewhere within the age range determined for some senior unit. There is no need to fill in age information for each unit. If no information is entered, the database searches up the stratigraphic hierarchy of the unit and the computed ages default to those for the first unit that has entries. The database also searches for an age in other units that are considered to be the same age as the current unit or one of its senior units; this sideways search is enabled by making the same entry in the 'Synonymy, age' field for the two units of equivalent age (the entry can be typed in or taken off the pop-up menu). For example, only one set of age information is entered for all the units in the Buchans and Roberts Arm groups because the two groups are considered to be lateral equivalents. The age information is entered in the record for the Buchans Group and 'Buchans Group' is entered in the 'Synonymy, age' field on both this record and on the record for the Roberts Arm Group. All units in the Roberts Arm Group search up the stratigraphic hierarchy until they come to the record describing the group itself, which directs them to take age information from the Buchans Group. All units in the Buchans Group search up their stratigraphic hierarchy and take their age from the same record. The 'Rank/synonym providing age' field indicates from which record the information was derived, in this case 'Buchans Group'. Every unit must have radiometric and/or stratigraphic age information available to it, either directly or by default. As a minimum requirement, therefore, the record at the top of each stratigraphic hierarchy must have directly entered age information or an entry in the 'Synonymy, age' field.

Map legends are generally sorted by age (as well as other criteria). In many cases, however, a number of units will all return the same age information because they all default to the same senior unit, even though their relative ages are known to be different from geological relationships. Even for units whose relative ages are not known, there may be a preferred legend order. Sorting of these units is done using the 'Unit is younger than' field and follows a number of conventions. The most important of these is that units within a senior unit, for example formations within a group, are kept together on the legend, and not mixed with units from another senior unit. The database enforces these conventions by only allowing the entry of values appearing on a pop-up menu. For instance, if the record for the Sandy Lake Formation of the Buchans Group is open, the only units that will appear on the pop-up menu will be other formations of the Buchans Group or sub1-units that are direct subdivisions of the Buchans Group (i.e., they do not belong to formations or members). These units, and only these units, may be ordered relative to each other. If no entry is made in the 'Unit is younger than' field, the 'Ordering number' field defaults to 1. If an entry is made, the database looks up the 'Ordering number' for the unit that is entered and adds 1 to it. Ordering is done at five stratigraphic levels, from 'Supergroup' down to 'Sub1-unit', and at a sixth level, which allows mixing of sub2- and sub3-units. The ordering process is quite complex but the user is not exposed to the complexity because all the acceptable options are presented on the pop-up menu. In general, relative ages should be entered for junior units within a stratigraphic hierarchy. The most senior units generally sort themselves successfully using just radiometric and stratigraphic ages. If anomalies occur on the legend because two senior units return the same age limits, relative age entries can be made for these particular units to correct the situation. A procedure is provided to check for potential sorting problems (see below).

Synonymy, lithology. This is an optional field similar to 'Synonymy, age'. The difference is that lithological similarity is implied, but not age equivalency, and the field is not used by any computed variables. A possible use might be entering 'ophiolite' for all units with an ophiolitic association, so that these can be easily extracted from the database. The field can be typed into or a pre-existing value can be taken off the pop-up menu.

Rock class. This field should be filled for all records, including bracketed "dummy" units, and is used for legends that are sorted by rock class (i.e., ones that separate litho-stratigraphic, intrusive and lithodemic units). A value is taken off the pop-up menu.

Unit status. Either 'formal' or 'informal' should be taken of the pop-up menu for all units, including "dummy" units.

Lexicon entry? Either 'yes' or 'no' can be taken off the menu to indicate whether the unit is described in the Lexicon of Canadian Stratigraphy (Williams *et al.,* 1985). The main purpose of the entry is to make it easier to interface the database with a digital version of the lexicon at some future date.

Legend description. A description must be entered for all units except bracketed "dummy" units, but including subdivisions of "dummy" units. At the lowest level in the stratigraphic hierarchy, the description will probably come directly off the legend of a published geological map. If there are several descriptions to choose from, the most informative should be used; if the descriptions seem to have significantly different content, this may be an indication that units have been equated that should not have been equated. Descriptions for more senior units may never have appeared on a map legend; these can usually be compiled by combining descriptions from junior units. The Lexicon of Canadian Stratigraphy (Williams *et al.,* 1985) is a good source of descriptions for the highest level units.

Description reference. A reference must be entered for every 'Legend description' to indicate what publication it was taken from. The reference will be printed on the legend at the end of each description. This is necessary because, on a composite geological map, the description that is applied to a particular unit on a particular map may not have been written by the author of the map. Descriptions that are entered *verbatim* should be referenced in the usual manner. Descriptions that have had significant editing or are a combination of descriptions, but nonetheless still clearly reflect the content of the original, should be prefaced with 'comp.' for compiled. Up to two references can be entered for a description, separated by a semicolon. Descriptions that are written by the database compiler from a reading of the general literature are referenced as 'comp. various sources'. Entries can be typed in the first time they occur, but thereafter should be taken off the pop-up menu so as to save time and to ensure consistent spelling.

Summary rock type. Values must be taken off the pop-up menu for all units except "dummy" units. The menu presents a hierarchical list of rock types and the one that most closely describes the majority of rocks within a unit should be chosen. It is intended that the variable will be linked at a future date to a colour table so that a palette of colours appropriate to a unit's rock type can be presented to the user. This would be used to automate the colouring of a map and would provide some consistency in the colour schemes of maps produced from the system. In the meantime, the variable is a convenient way of highlighting or grouping units by rock type, and this capability has been built into ArcView™ maps derived from the system.

Command Buttons

Check for duplicate labels. Lists units and labels at the top level of each stratigraphic hierarchy. It is organized alphabetically by 'Incremental label' and makes it easy to identify labels that are not unique, even when the age component is included.

Check for ambiguous ordering numbers. Opens two windows for checking whether all necessary information has been included in the 'Unit is younger than' field, which in turn controls the 'Ordering number' field. The first window lists units at the top level of each stratigraphic hierarchy, sorted by age. Units that have the same age for both base and top should have different 'Ordering numbers' to allow proper sorting in the legend; any that do not are easily identified on the list. The second window lists units that have entries in the 'Synonymy, age' field. Units with the same entry in this field should have different 'Ordering numbers' to allow proper sorting.

Table 5: Timescale

Figure 7 shows the form presented to the user for entering information on the timescale. *Table 5* makes it easy to adjust all maps and legends produced from the system for changes in the calibration of the geological timescale. Any changes entered into this table are immediately reflected in the age component of unit labels and in the organization and age titles of legends. Once set up for a particular region, the table is unlikely to need revision except when parts of the timescale are recalibrated.

Variables

Time interval. The name of any time interval that is defined in the timescale, such as Phanerozoic, Ordovician, Llandovery or *D. clingani* (zone). All the names entered in this field are listed on the pop-up menus on *Table 4* (Figure 6) for 'Stratigraphic lower/upper age limit' and so the variable is one of the keys linking *Tables 4* and *5*.

Rank. All available values are listed on the pop-up menu. They give the rank of the 'Time interval' in terms of the

Time interval	Middle Ordovician
Rank	Subperiod (Subsystem) ▼
Label	mO
Age of top	458
Source for age of top	Tucker and McKerrow (1995)
Age of base	470
Source for age of base	Tucker and McKerrow (1995)
Ordering number	9

Open input table:

[*] Table 1: Polygon IDs
[*] Table 2: Unit IDs
[*] Table 3: 1 to 1 million
[*] Table 4: Unit descriptions
[*] Table 6: References

Select records:

[* * * * *]

Go to "Output Selection":

[* * * * *]

Figure 7. Table 5: *Timescale. Form used to enter data from the geological timescale.*

hierarchy of geochronologic units in the stratigraphic code (North American Commission on Stratigraphic Nomenclature, 1983). Geochronologic units are used because the database is dealing with divisions of time defined in millions of years, rather than in bodies of rock. The 'other' value (see Figure 6) allows entry of two parallel sets of time intervals of the same rank, e.g., Ordovician graptolite zones may be identified with the 'chron' (zone) rank and Ordovician conodont zones with 'other'.

Label is the letter or letters used in the age component of map unit labels. This variable is accessed by *Table 4* to build a unit label.

Age of the top/base. The age limits of the 'Time interval' in millions of years. Indirectly, these are keys linking *Tables 4* and *5*. The computed ages of units in *Table 4* are compared with the ranges defined by these two fields in *Table 5* so that the age component of a label and age titles in the legend can be determined. Fields are provided for references to age information as an aid to the database compiler.

Ordering number. The number entered in this field on some records is used to help sort legends.

Table 6: References

Figure 8 shows the form presented to the user for entering references into the database.

Variables

CARIS ID is the number assigned to an individual geological source map for use in CARIS™.

Map ID is the number assigned to a source map for use within the database. This is the key linking *Table 6* to *Tables 1* and *2* (Figures 2 and 4), and one of the keys linking it to *Tables 8* and *10*. It corresponds to the number used for the reference in the Geological Survey Geofiles.

Authors. The authors are entered into separate fields to allow sorting. If there are more than four authors, the rest are entered as a text string in the 'Author 4' field.

Year and *letter*. Provides the year and a suffix where there is more than one reference by the same author in the same year.

Other reference information. Five fields provide the other necessary information for building a reference. Maps themselves are referenced, not simply the publications in which they appear.

Short reference. The short form of the reference is used as the key linking *Table 6* to *Table 4* (Figure 6), by way of computed variables derived from 'Description reference', and is one of the links with *Tables 8* and *10*.

CARIS ID	DM008
Map ID	NFMAP 94-228
Author 1	Kean, B.F.
Author 2	Evans, D.T.W.
Author 3	Jenner, G.A.
Author 4	
Year	1994
Year letter	b
Map title	Geology and mineral occurrences of the Little Bay Islands map area (Map 94-228) Whole rock geochemistry sample locations of the Little Bay Islands map area (Map 94-229).
Map number	94-228; 94-229
Source publication	Geology and mineralization of the Lushs Bight Group.
Publisher	Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey
Volume, pages etc.	Report 95-2, 203 pages
Short reference	Kean et al., 1994b
Full reference	Kean, B.F., Evans, D.T.W. and Jenner, G.A. 1994b: Geology and mineral occurrences of the Little Bay Islands map area (Map 94-228) Whole rock geochemistry sample locations of the Little Bay Islands map area (Map 94-229). Map 94-228; 94-229. In Geology and mineralization of the Lushs Bight Group. Government of Newfoundland and Labrador, Department of Natural Resources, Geological Survey, Report 95-2, 203 pages. GS# NFMAP 94-228.

Open input table:

- [*] Table 1: Polygon IDs
- [*] Table 2: Unit IDs
- [*] Table 3: 1 to 1 million
- [*] Table 4: Unit descriptions
- [*] Table 5: Timescale

Go to "Output Selection":

[* * * * *]

Select records:

[* * * * *]

Print reference list:

[* * * * *]

Dump reference list:

[* * * * *]

Figure 8. Table 6: *References. Form used to enter reference data.*

Full reference. This is the full reference constructed from the various input fields using the standard Geological Survey format.

Command Buttons

Print reference list. Prints a list of references as displayed in the 'Full reference' field, sorted by author and year, for records meeting the criteria specified by 'Select records'.

Dump reference list. Dumps (downloads) the same list as in 'Print...' to a text file.

SUMMARY OF INPUT PROCEDURE

The detailed description of tables, variables and command buttons tends to obscure what is really involved in entering data into the database. At present, the database holds records for an area of about 960 km² in central Newfoundland, equivalent to about fifteen full 1:50 000-scale map areas, and representing about 13 percent of the island portion of the province. This dataset is organized as follows:

Input table	Number of records	Records depend on area	Number of entry fields	Fields by method of data entry: Text file	Posting	Menu only	Menu or typing	Calc. or typing	Typing only
1	2165	yes	5	5	-	-	-	-	-
2	473	yes	10	-	2	1	7	-	-
3	55	no	7	-	-	3	-	-	4
4	455	yes	31	-	7	7	3	2	12
5	130	no	8	-	-	1	-	-	7
6	198	no	13	-	-	-	-	-	13

Tables 3, 5 and *6* (Figures 5, 7 and 8) already contain all necessary records for complete coverage of the island. As coverage increases, only *Tables 1, 2* and *4* (Figures 2, 4 and 6) will show a proportional increase in their number of records.

The following describes the typical data entry process.

Table 1

A 1:50 000 scale-map sheet in insular Newfoundland is likely to have between twenty and four-hundred polygons. The easiest way to enter these data is first to assemble them on a spreadsheet. The first column on the spreadsheet is the 'Map ID', which is the same for all the rows (records). It can therefore be entered once in the first row and copied to all the other rows. The 'Polygon ID' is, for the most part, a sequential number from one upward. Again this is easily generated by a formula in the second row, which can be copied to all the other rows. The 'Unit ID' has to be entered for each record individually and this creates the most work and has the greatest potential for error; the wrong 'Unit ID' in a record will lead to the polygon being incorrectly labelled on the map and may produce a spurious entry on the legend. 'Priority' can initially be entered as 1 in the first row and copied to all the other rows. In the few cases, where a record with 'Priority' greater than 1 is required the value can be edited or a new row inserted. The 'Added characters' field is left blank in most records.

Once the file is assembled on the spreadsheet, it can be saved as a text file and then entered into *Table 1* (Figure 2) by clicking the 'Load' button. Clicking the 'Post...' button then allows work to proceed on *Table 2* (Figure 4).

Table 2

The records that need to be completed can be selected by choosing the appropriate 'Map ID' using the 'Select records' button. 'Map ID' and 'Unit ID' are already entered by the 'Post...' function. A typical map sheet has between ten and forty different units that need to be defined. Most of the work is in deciding how to classify them, but much of this will already have been done on the legend of the source map. For insular Newfoundland, entering the '1:1-million label' is a matter of choosing one of fifty-five values off a menu. Names entered in the 'Supergroup' to 'Member' fields have to be typed into the database once and thereafter are taken off menus. Entries for the subunit fields have to be typed in, but are mostly single letter values.

When all records have been completed, the unit names are posted to *Table 4* (Figure 6) by clicking the 'Post...' button.

Table 4

Records that need to be completed can be found by selecting records in which 'Unit status' is undefined.

Potentially every record in *Table 2* can generate seven records in *Table 4* (Figure 6), one for each level on the stratigraphic hierarchy. However, in actual practice the number of records in *Table 4* is about the same as in *Table 2* because many of the stratigraphic fields are left empty and many units are common to two or more map sheets. A unit that occurs on two map sheets has two records in *Table 2*, but only one set of records in *Table 4*.

The seven stratigraphic fields are already filled by the 'Post...' function, which leaves a maximum of twenty-four other fields to be filled. 'Incremental label' requires the typing of one or two letters, unless the record is for a subunit in which case the field is filled automatically. The 'Unit is younger than' value is taken off a menu and the choice should be fairly obvious from the legend on the source map; a reference can be entered if desired. 'Ordering number' is calculated automatically but can be edited. Stratigraphic and/or radiometric age information is entered into perhaps 10 percent of records, the rest simply defaulting to values provided by more senior or synonymous units. The stratigraphic age limits are taken off menus and only the radiometric ages have to be typed. Names entered into both of the synonymy fields only have to be typed in once and thereafter appear on menus; the 'Synonymy, age' field is usually unfilled. Values for 'Rock class', 'Unit status', 'Lexicon entry?' and 'Summary rock type' are all entered off menus. Each 'Legend description' has to be compiled and typed in individually, but in about half the records it can be copied directly off the legend of the source map. Each 'Description reference' has to be typed in once and can afterwards be taken off a menu.

Tables 3, 5 and 6

Once set up for a particular region, these three tables require very little maintenance. The most active is likely to be *Table 6* (Figure 8). Currently it holds references to all maps indexed by Colman-Sadd *et al.* (1995) for insular Newfoundland, together with a few other references required for legend descriptions. New maps, perhaps five each year, will need to be entered as they are made and digitized.

OUTPUT TABLES

Table 7: Output Selection

Figure 9 shows the form presented to the user by *Table 7*. Everything that is required to extract data for map production is on this form.

Loading Data

Two options are available. In most cases, a map is likely to be produced from the mosaic of maps for the island. An area is selected in CARIS™ and a text file is produced that lists the identifying numbers for all the polygons within the area. The user clicks on the button 'Load Map and Polygon IDs from a text file' and a dialogue box opens asking for the text file to be selected from a menu. Once the file is selected, the database loads it into *Tables 8* and *8a*, which are invisible to the user, first deleting any records present in these tables from a previous map. The identifying numbers are reformatted as separate 'Map ID' and 'Polygon ID' fields, and 'Unit ID', 'Priority' and 'Added character' values are posted from *Table 1* (Figure 2) for each polygon, so that a subset of *Table 1* is created for the area in question.

If 'Load Map and Polygon IDs from Table 1' is clicked, a query form is presented that allows the user to select records from *Table 1*. These are then posted to *Table 8* to produce a subset of records, as in the case with the text file. A common use of this option might be to select all the records for a particular 'Map ID'. The output could then be used with the individual digital copy of this map to produce a version that perhaps has different levels of detail from the original.

Selecting the Level of Detail

When data have been loaded into *Table 8*, the user can select the level of detail required for the map. Each copy of the form (*Table 7*) shown in Figure 9 represents one record. The first record should be designated as the 'Default' and should be given the user's choice of detail, ranging from '1:1 million' through 'Supergroup' to 'Sub3-unit' (all values are chosen from pop-up menus). All units that are not specifically identified on subsequent records will default to this level of detail. If 'Sub3-unit' is chosen and no other records are created, the map will have the same level of detail as the source maps. If 'Group' is selected, the map will show units undivided below the group level. Units that do not have an entry in the 'Group' field, default up the stratigraphic hierarchy and use 'Supergroup', if it is available. If both 'Group' and 'Supergroup' are unspecified, the unit uses the first defined field down the hierarchy.

For each unit that is to have a particular level of detail, a new selection form, representing a new record in *Table 7*, must be filled out. The number of current records is shown to the right of the seven stratigraphic fields. The stratigraphic fields cannot be typed into; values must be selected off the pop-up menus. The menus only show units that are represented by polygons currently loaded into *Table 8*. Also a senior unit must be entered in its field before its subdivisions will appear on the menu in a lower ranked field.

There are many different ways in which a map can be customized. Two examples are described.

Click a button to load data:

Load Map and Polygon IDs from a text file: [*]

Load Map and Polygon IDs from Table 1: [*]

Select level of detail: Sub3-unit ▼

Select "Default" and a level on one record: ▼

Units that are not listed separately will default to this level.

N.B. Under most circumstances, if the "1:1 million" level is selected, "Default" should also be selected and no other levels of detail should be specified for individual units. "1:1 million" units are not based on the stratigraphic code and should not normally be mixed with units that are.

For different levels of detail for different units, use the form below and the instructions to the right:

Supergroup	▼
Group	Roberts Arm Group ▼
Formation	▼
Member	▼
Sub1-unit	▼
Sub2-unit	▼
Sub3-unit	▼

1. Create a separate record for each unit that is to have a different level of detail from the "Default" record ("Clear Form" on the "View" menu).
2. Select a unit from "Supergroup", "Group" or "Formation". The level of division will apply to all subdivisions within the selected unit.
3. If different levels are required for different subdivisions within a senior unit, specify levels and subdivisions on individual records.
4. If a subdivision of a senior unit should have a special level of detail, so that it stands out from the rest of the unit, select a level on a separate record and then select the name for that subdivision in the "Supergroup", "Group", "Formation" etc. fields.

This form currently has [2] record(s), each representing different levels of detail. Use "Find First", "Find Next" and "Delete" on the "View" menu to remove unwanted records.

Click button to open input table:

Table 1: Polygon IDs [*]

Table 2: Unit IDs [*]

Table 3: 1 to 1 million [*]

Table 4: Unit descriptions [*]

Table 5: Timescale [*]

Table 6: References [*]

Click a button to dump data for a map and/or to create a legend with references:

Dump data file for ArcView and make age-only and 1:1 million legends: [* * * * *]

Dump polygon data ...

and make an age-only legend: [*]
and make an age/zone legend: [*]
and make an age/rock class legend: [*]
and make an age/zone/rock class legend: [*]
but don't make a legend: [*]

Don't dump polygon data, just make ...

an age-only legend: [*]
an age/zone legend: [*]
an age/rock class legend: [*]
an age/zone/rock class legend: [*]

Format most recent legend as ...

an age-only legend: [*]
an age/zone legend: [*]
an age/rock class legend: [*]
an age/zone/rock class legend: [*]

N.B. For a 1:1 million style map, the best choice is an age/zone/rock class legend

Dump most recent reference lists: [*]

Figure 9. Table 7: *'Output Selection' form used to retrieve data for the production of geological maps, legends, data files and reference lists.*

1) In Open File NFLD/2513 (Liverman *et al.*, 1995), the bedrock geology map shows all subdivisions of the Roberts Arm Group, but other units are undivided. This result was achieved with two selection form records. The first was the 'Default' record and 'Supergroup' was selected as the level of detail. On the second record (example in Figure 9), the 'Default' field was left empty and 'Sub3-unit' was selected as the level of detail. 'Roberts Arm Group' was then entered from the pop-up menu in the 'Group' field. This had the effect of overriding the default record and showing all subdivisions of the Roberts Arm Group down to the 'Sub3-unit' level.
2) The following procedure would produce a map, in which the Buchans Group is split into formations and then a pyroclastic breccia unit is separated out of the Buchans River Formation. A 'Default' record is produced with 'Supergroup' selected so that all units, other than the Buchans Group, are generalized as much as possible. A second record has 'Formation' selected as the level of detail, an empty 'Default' field, and 'Buchans Group' entered into the 'Group' field; this record splits the Buchans Group into formations. A third record has 'Sub3-unit' as the level of detail and the 'Default' field is empty; 'Buchans Group' is entered in the 'Group' field, 'Buchans River Formation' in the 'Formation' field, the 'Member' field is empty because there are no members, 'v' is entered in the 'Sub1-unit' field, 'd' in the 'Sub2-unit' field, and 'x' in the 'Sub3-unit' field; this copy of the form picks out and separates the pyroclastic breccia unit, OBBvdx, which is a division at the Sub3-unit level.

Data Output

A number of options are presented for data output. Each one is selected by clicking a command button (Figure 9).

Clicking a button in the first column, first of all, dumps a text file consisting of 'Map ID' and 'Polygon ID', reformatted into the identifier used in CARIS™, and two computed variables defining new unit labels for the map polygons. All labels are adjusted for the levels of detail to be shown on the map. The file is imported into CARIS™ and used to label the polygons on the map. The first of the unit labels refers to the dominant unit in the polygon, the second label includes all the units in the polygon, as well as 'Added characters'. Most units have the same label in each field. Five records from a text file might be as follows.

Map ID and Polygon ID reformatted for CARIS™	Label of dominant unit	Full label
DM008_33	OWp	OWp
DM008_34	OWp	OWp
DM008_36	OWp	OWp?
DM008_37	OWp	OWp, Od
DM008_45	OWp	OWp?, Od

The label of the dominant unit determines colour, and whatever colour is assigned to unit OWp will be used for all five polygons. The full label also lists an unseparated subsidiary unit in polygons 37 and 45 and includes question marks in polygons 36 and 45 where the geologist was unsure of the unit identification. Although all five units should be coloured the same, only polygons 33 and 34 actually are the same, as shown by the full label. If these two polygons are adjacent, the GIS dissolves the contact between them so that they appear as one. Polygons 34 to 45 are all different and their contacts will remain, even if they are adjacent to each other, and even though they have the same colour.

Unless the last button was clicked, the database prepares a map legend after dumping the polygon data. It does this by opening *Table 9*, which stores the legend and, like *Table 8*, is invisible to the user. The previous contents of *Table 9* are deleted and information needed for the new legend is posted from *Table 8*. Sorting variables are calculated, and then the legend is dumped to a text file. Its organization and headers depend on which button was clicked. The text file requires no further formatting other than some global changes to tabs and carriage returns and the selection of point sizes and text styles.

Table 8 also posts a list of 'Map IDs' and 'Description references' to *Table 10*; the latter are derived from *Table 4* (Figure 6). In *Table 10*, which is invisible to the user, the full references for maps and legend descriptions are looked up from *Table 6* (Figure 8). Two lists of references are then dumped to text files, the first for linework on the map, and the second for any legend descriptions that are not already referenced in the linework list.

If only a legend is required, and no polygon data, one of the buttons in the middle column can be clicked. The buttons in the right column are used for dumping the legend and reference lists currently held in *Tables 9* and *10*. The legend can be dumped in any format. They bypass the time-consuming process of posting data and calculating sorting variables.

Clicking the button for dumping ArcView™ data, dumps a data file that allows manipulation of the map in the ArcView™ environment (Honarvar *et al., this volume*). A typical record is shown in Figure 10. Variables are included that allow the map to be displayed at any level of detail, including different levels for different units, and to be searched by name of unit, age, rock type or tectonostratigraphic zone. Secondly, the button dumps text files of the map legend organized (a) into stratigraphic units at the most generalized level of subdivision, sorted by age, (b) into stratigraphic units at the most detailed level of subdivision, sorted by age, and (c) according to the classification scheme on the 1:1-million scale map of Newfoundland, sorted by zone, rock class and age. The legends are made accessible in ArcView™ as Windows help files. Lastly, a reference list is dumped for the maps and legend descriptions in the selected dataset, and is also made accessible as a help file.

CONCLUSION

The initial impetus for this project was the need to produce digital bedrock geology maps at different scales and levels of detail for different uses. If this had been done in the traditional way, it would have been necessary to digitize coverage of insular Newfoundland at least three times, at the 1:50 000, 1:250 000 and 1:1 000 000 scales. Digitizing is labour-intensive and expensive. It is minimized by using the present system because only one set of digitized maps is required. The trade-off is that data must be entered into a database, but a method has been designed that makes this relatively quick, easy and error-free. It takes much less time to enter the data for a map sheet than it does to digitize the linework.

Controlling maps from a database has many advantages apart from economy. It allows the maps to be flexible in presentation, to be searchable on a variety of criteria, and to have easily updated unit labels and legends. Furthermore, the database has uses independent of the map. Amongst other things, it provides a list of age limits for stratigraphic units, a detailed and searchable timescale, and a searchable list of the most recent maps available for insular Newfoundland. It also allows the linking of other existing or potential databases, such as the geochronology database (Mandville, 1990), the Mineral Occurrence Database (Stapleton and Parsons, 1991), or a computerized version of the Lexicon of Canadian Stratigraphy (Williams *et al.,* 1985). Variables that are dependent on some aspect of bedrock geology can be added to the database and used to produce thematic maps. For instance, if units are classified for their suitability as sources of bedrock aggregate, using the three-fold division of Bragg (1995), the database can be instructed to dump a polygon list with labels indicating bedrock aggregate quality, instead of geological unit. The same procedure as is used to produce a conventional geology map would then produce a map of bedrock aggregate geology, similar to Figure 2 of Bragg (1995), at a level of detail appropriate to the scale. Likewise units can be classified for mineral potential, either for individual commodities or for all commodities, and mineral potential maps can be generated.

The alteration of original data produced by field geologists is a continuing concern. Any effort to gather information together in a consistent form inevitably requires changes. The philosophy in this project is to make changes where the compiler of the database has the benefit of extra geological information not available to the field geologist, but to leave unchanged data that have not been superseded by new observations. Following this philosophy, stratigraphic classifications, particularly where they depend on new age determinations, are open to revision. On the other hand, the positions of contacts are not because, if there were new geological observations of a substantial kind, there would be a new map, which would replace the one currently in the system. Some contacts could be repositioned on the basis of later geophysical or geochemical data, but since these datasets are likely to be available on the same GIS as the geology map, their interpretation is best left to the end user. The references, which reflect the decoupling of the linework from the legends, have deliberately been made into an automatic product of the database, so that the user has to make a conscious decision to delete them from the legend descriptions and to omit the reference lists from the map.

The present system is a prototype residing on a number of different computer platforms and using software that is not widely distributed. The objective throughout has been a generic product. What is important is the nature of the data that are put into the system and the nature of the data that come out. The details of the programs that actually manipulate the data will vary from one hardware/software combination to another. At the Newfoundland Geological Survey, it is intended to integrate the system on a single server, using CARIS™ as the graphical end of the GIS and ORACLE™ as the database. If it appears to be warranted, it should be reasonably easy to implement the underlying concepts on other systems using other GIS software. In the meantime, output in the form of linework and text files can easily be exported, as is demonstrated by the current use of the data in ArcView™.

General Information

ArcView Polygon ID	005017
Map ID	NFLD/0979h
Map reference	Dean, 1977h

Data for polygon at level of detail chosen in Table 7: Output Selection

Label of dominant unit	eSSvf
Full polygon label	eSSvf, eSSvb
Dom. unit ordering number	8888143514249899999997
Summary rock type	volcanic, felsic non-marine
Age range of unit	Early Silurian
Age of base of unit	435
Age of top of unit	424
Supergroup	
Group	Springdale Group
Formation	
Member	
Sub1-unit	v
Sub2-unit	f
Sub3-unit	

Data for polygon at minimum level of detail (Supergroup)

Unit name	Springdale Group
Label of dominant unit	eSS
Full polygon label	eSS
Dom. unit ordering number	8888143514249899
Summary rock type	volcanic, non-marine
Age range of unit	Early Silurian
Age of base of unit	435
Age of top of unit	424

Data for polygon at 1:1 million level of detail

1:1 million label	Sv
1:1 million ordering n'r	5
Zone +/- Subzone	Post-Ordovician Overlap Sequences
Zone ordering number	1

Figure 10. *A single record from a data file produced by clicking the ArcView button in the 'Output Selection' form. 'ArcView Polygon ID' is a combination of 'Map ID' and 'Polygon ID', reformatted as a purely numeric value for use with dBase files. Ordering numbers are used for ordering the legends in ArcView™. 'Label of the dominant unit' is the label of the principal unit in a polygon, which is used to determine the colour of the polygon. 'Full polygon label' includes unseparated subsidiary units and added characters such as question marks. Note that this record is for the same polygon 17 as is represented by two records of different priority in* Table 1 *(Figure 3); these two records generate a compound label, 'eSSvf, eSSvb', at the most detailed level of subdivision, but a simple label at the minimum level of detail because both units generalize to 'eSS'.*

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